

# BASIN RECHARGE OF PLAYA WATER

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**ABSTRACT:** A 0.20-ha (0.5-acre) recharge basin was tested for conserving storm runoff that collected in a 16-ha (40-acre) playa in the Southern High Plains. The basin was constructed by removing 1.2 m (4 ft) of soil to expose permeable sediments. Turbid water was pumped from the playa to the basin during eight tests over a 7-yr interval. Average recharge rate during 187 days of flooding was 0.373 m/d (1.22 ft/day). After three recharge tests during the first year, no maintenance was done to the basin bottom. Our research showed that recharge basins could be an effective technique for partially replenishing the depleted Ogallala Aquifer.

## INTRODUCTION

Artificial groundwater recharge has been studied extensively as a technique for conserving storm runoff that accumulates in playas (wet weather lakes) in the Southern High Plains. The playa water would be used to partially replenish groundwater that is being mined from the Ogallala Aquifer (3).

Economically feasible groundwater recharge systems have not been developed because of the spatial and temporal variability of the water supply and the geology of the area (2,6). Playa water is randomly available in about 17,000 playas in the Southern High Plains depending on rainfall. With the large number of water sources, the limited quantity of water at each location, and the random availability, large investments for individual ground water recharge structures cannot be justified. The high suspended solids content of the playa waters has caused most recharge wells to fail by clogging the aquifer near the well bore or screen. Hauser and Lotspeich (5), developed a water clarification system for field use, but high costs and operating complexity keeps the system from being adopted. Most soils of the Southern High Plains are fine textured, and thus, not suitable for groundwater recharge by surface spreading. Research with surface recharge structures was limited until the innovative work by Aronovici et al. (1).

In 1969, Aronovici and his colleagues removed the entire 1.2 m (4 ft) profile of Pullman clay loam to expose sediments many times more permeable than the soil itself. An initial test with clear well water showed a potential recharge rate as high as 2 m/d (6.6 ft/day). In subsequent tests with turbid playa water, the initial recharge rates were as high as 1 m/d (3.3 ft/day). After the initial high rates, percolation always slowed because of sealing by the suspended solids.

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Extensive research was conducted in a 0.04-ha (0.1-acre) recharge basin to investigate sediment penetration into the basin surface and the feasibility of renovating a sealed basin surface. In a study using sediment tagged with  $^{134}\text{Cs}$ , Goss et al. (4) showed that 92% of the suspended solids were filtered within 25 mm (1 in.) of the basin surface. Since the sediments were filtered at the basin surface, Jones et al. (7) were able to remove the sediments after they had dried and separated from the basin surface. During eleven recharge cycles with the 0.04-ha (0.1-acre) recharge basin, they recharged 132 m (432 ft) of turbid water at an average rate of 0.433 m/d (1.42 ft/day). Preliminary tests with 0.20-ha (0.5-acre) and 0.40-ha (1-acre) basins showed similar results.

The recharge potential of the small basins illustrated a need for testing the basin recharge concept in basins large enough to recharge all the water from a single playa within a reasonable time. The results also showed the need for treatments and techniques to increase recharge rates and reduce the basin renovation time. Jones et al., (8) reported management practices to increase recharge rates of playa water and reduce surface sealing by suspended solids. This paper presents the results of testing a 0.20-ha (0.5-acre) basin from 1971–1978 to evaluate a prototype basin recharge system.

**Basin Description.**—The basin was excavated along the north margin of a playa located 48 km (30 mile) west and 16 km (10 mile) south of Amarillo, Tex. Figure 1 illustrates the location of the recharge basin and pumping station at the edge of the 16-ha (40-acre) playa. The basin was 100 m (330 ft) long, 20 m (66 ft) wide, and approximately 1.2 m (4 ft) deep. Excavated soil was used to form a protective dyke around the basin.

The slowly-permeable Pullman soil was entirely removed to expose a 0.3-m (1-ft) thick caliche (calcium carbonate) layer overlying permeable

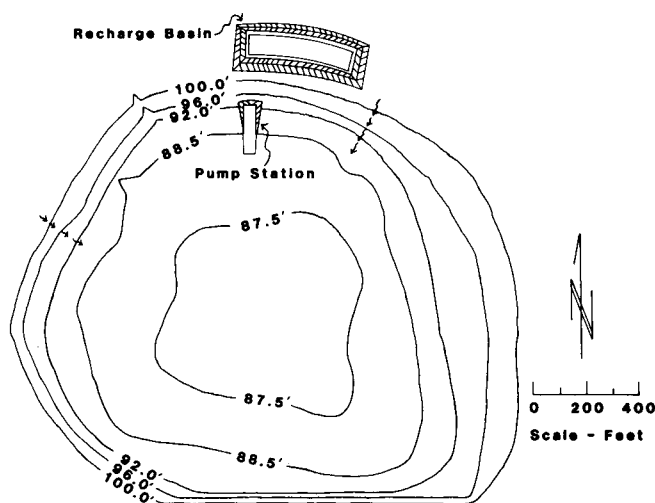
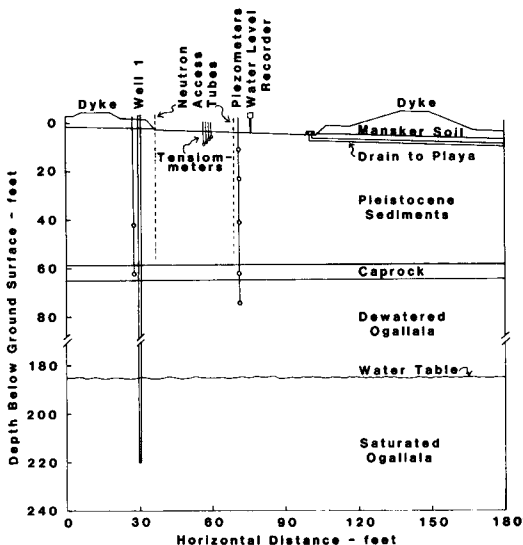


FIG. 1.—Location of the Recharge Basin at the North Edge of the 16-ha (40-acre) Playa. (1 ft = 0.305 m)



**FIG. 2.—Cross Section through N-S Centerline of Basin Showing Instrumentation and Basin Drain. Depth is Below Original Ground Surface at the Center of the Basin. (1 ft = 0.305 m)**

Pleistocene age sediments shown in Fig. 2. The Ogallala Formation at the recharge site is 18 m (60 ft) below the ground surface. The geology is similar to that described by Aronovici et al. (1).

The recharge basin was instrumented to measure recharge rates and to determine barriers to soil water flow. Locations of neutron access tubes, piezometers and a well to the aquifer are illustrated in Fig. 2. A group of four tensiometers was installed at depths of 51 mm (2 in.) to 610 mm (24 in.) for measuring the head loss across the basin surface. Inflow to the basin was measured with a propeller meter in the pipeline, and water levels in the basin were continuously recorded. The pumping lift from the playa to the recharge basin was about 5 m (16 ft).

Initially, the basin was corrugated along the contour with 1-m (40-in.) wide ridges and furrows. After the third recharge test in Sept. 1972, the basin was recorrugated with similar sized corrugations running up and down the slope. At the same time, a basin drain was installed which removed rainfall runoff during storm and permitted emptying the basin after tests. After Sept. 1972 no additional preparation or renovation was done to the basin surface.

## PROCEDURE

Recharge tests were conducted so that accurate daily recharge rates could be calculated and barriers to soil water flow could be determined. During the first three tests, the flooding depth was held constant, but during the remainder of the tests, the basin was filled daily and the water level was allowed to drop during a 24-hr interval. Neutron soil

moisture and gamma-ray soil density measurements were made during the initial test of the basin. Piezometer water levels were measured daily throughout each of the recharge tests. Daily pumping volumes were recorded manually, and the basin water level was continuously recorded with a float operated recorder. Detailed tensiometer readings were made during selected tests.

The recharge tests were normally started one to two weeks after storm runoff became available in the playa. The delay allowed the initial high suspended solids content in the playa water to decrease, and it also allowed the basin surface to dry before being flooded. Tests were continued until the recharge rate approached 0.03 m/d (0.1 ft/day) or until the playa water supply was exhausted.

## RESULTS

Results of the eight recharge tests conducted over a 7 yr interval are listed in Table 1 and illustrated in Figs. 3 and 4.

The lengths of the recharge tests ranged from 4–35 days, and total recharge per test ranged from 1.0–19.4 m (3.3–63.6 ft). Total length of flooding was 187 days, and total recharge was 69.7 m (229 ft) for an average recharge rate of 0.373 m/d (1.22 ft/day).

Recharge rates varied extensively between tests and during tests, Figs. 3 and 4. The decline in recharge rates is typical of infiltration with turbid water; however, recharge rates during Tests 5 and 8 increased substantially until the 16th day of recharge and then declined. The highest recharge rates occurred during Tests 7 and 8 when the flooding depth was 1.8 and 2.0 times the flooding depth for Tests 1 through 6. The variability of the recharge rates during the constant head tests, Fig. 3, was partially due to the problem of maintaining a constant head.

Average suspended solids in the recharge water ranged from 73 mg/L for Test 5–638 mg/L for Test 6, Table 1. The lowest suspended solids content occurred during Test 5, when vegetation covered the playa bot-

**TABLE 1.—Summary Data for 0.20-Hectare (0.5-Acre) Recharge Basin**

Recharge test number (1)	Starting date (2)	Length of flooding, in days (3)	Total recharge, in meters (4)	Average recharge rate, in meters/day (5)	Average suspended solids, in milligrams/liter (6)	Total filtered solids, in kilograms/meter <sup>2</sup> (7)	Flooding depth, in meters (8)
1	Oct. 4, 1971	31	11.1	0.358	150	1.66	0.76
2	Nov. 18, 1971	11	2.6	0.236	231	0.60	0.76
3	Dec. 20, 1971	4	1.0	0.250	200	0.20	0.76
4	Sept. 5, 1974	29	9.7	0.334	408	3.96	0.76
5	Nov. 4, 1974	24	6.4	0.267	73	0.47	0.76
6	June 5, 1978	18	4.8	0.267	638	3.06	0.76
7	July 10, 1978	35	14.7	0.420	152	2.23	1.37
8	Oct. 2, 1978	35	19.4	0.554	262	5.08	1.52
Total or average		187	69.7	0.373		17.30	

Note: 1 meter = 3.28 feet; 1 kilogram/meter<sup>2</sup> = 0.204 pounds/foot<sup>2</sup>.

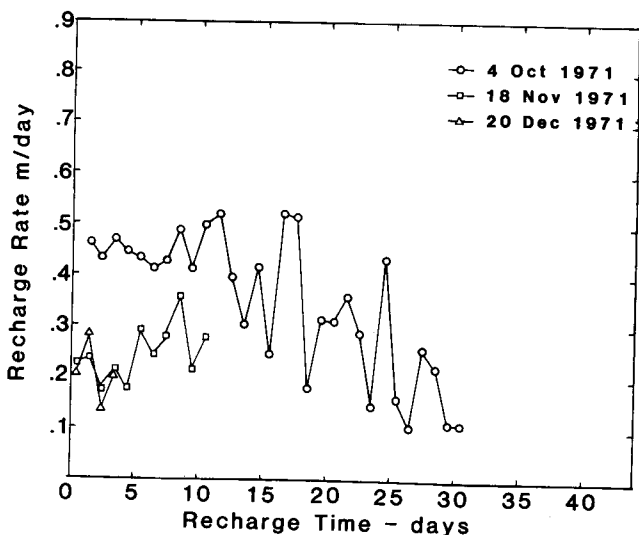


FIG. 3.—Recharge Rates for the Constant Head Tests during 1971

tom and most solids settled from the water. The highest concentration occurred during Test 6 when highly turbid runoff was still entering the playa as recharge began. Because of the high variability of suspended solids concentrations and test lengths, total sediment deposited on the basin bottom varied by a factor of 5 among tests.

The results of this study are similar to the results of Aronovici et al. (1) and Jones et al. (7,8) in recharging turbid surface water through Pleis-

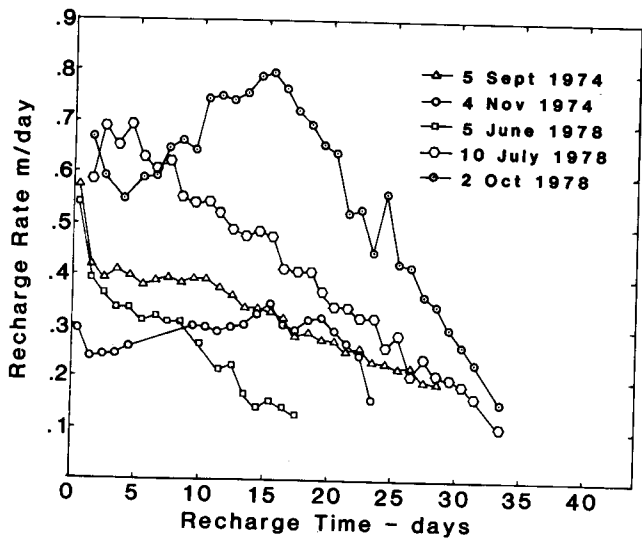


FIG. 4.—Recharge Rates for the Falling Head Tests during 1974 and 1978

tocene sediments. The soils and geology are identical to those reported by Aronovici et al. (1) except that the Ogallala Formation was overlain by a slightly thicker section. With neutron soil water data, we determined that the initial recharge water moved through the dry sediments with a distinct wetting front. After percolating water reached the indurated calcium carbonate layer ("caprock") overlying the Ogallala, a groundwater mound developed, but the mound height never exceeded the elevation of the recharge basin bottom surface. The water level in Well 1 rose as much as 3 m (9 ft) during recharge tests to verify that percolating water was recharging the aquifer. By using tensiometers near the basin surface we showed that the sealed basin surface was the controlling impedance to flow just as reported by Jones et al. (7). During Tests 5 and 8, the recharge rates increased during the first 16 days and then started the typical decline due to infiltration of turbid water. This was likely due to the under water soil cracking phenomenon reported by Jones et al. (7). Since the results of this study generally agree with those of three earlier studies of small basins, we conclude that results from the small basins can confidently be applied to larger basins.

The basin management procedures reported by Jones et al. (8) can increase the potential of recharge basins such as the one reported here. Their most important variable was the flooding depth. Nearly 50% of the water recharged through this basin was recharged during the last two tests with increased flooding depths. An organic filter on the basin surface and partial clarification of highly turbid water with polyelectrolytes further increased the total recharge during a flooding cycle (8).

An important development with this recharge basin was the use of the downhill corrugations and gravity drain to make the basin self-cleaning. Intense storms that contributed runoff water to the playa, also eroded the sealing layer from the bottom of the basin. The ridges and furrows increased the flow depth of rainfall and helped transport the sediments to the lower side of the basin. At that point, the gravity drain removed the sediment-laden water from the basin. The result was a maintenance free technique for removing filtered sediment from the basin surface. For that reason, basin maintenance was not required during the last six years that we used the basin. The effectiveness of the self-cleaning system is verified by the fact that recharge rates did not decrease with time, but actually increased during the high head tests at the end of the study.

In this study we showed that excavated recharge basins in the Southern High Plains are a physically effective method of recharging the depleted Ogallala Formation. The average recharge rate of 0.373 m/d (1.22 ft/day) was sufficiently high to recharge large volumes of water. The self-maintaining characteristic of the basin shows that it can be used for long periods of time without major maintenance expenses.

Recharge basins would ideally be one component of a playa water conservation system rather than the only conservation practice. Because of high energy costs for pumping groundwater, playa water is more economically utilized by pumping directly onto irrigated fields. Playa water is often available, however, when no irrigation demand exists. At those times, recharge basins could provide a method of conserving water that is now lost to evaporation.

The economics of the excavated recharge basins could be enhanced by making them a part of the total playa water conservation system. Pumps used to pump irrigation runoff and storm runoff directly from playas to irrigated fields, could also be used to fill recharge basins. Such use would eliminate the high cost of owning and maintaining pumping equipment for the small percentage of time a recharge basin is actually used. With multiple use of pumping equipment, the design and excavation of a recharge basin would be the major fixed cost. A recharge basin designed like the one in this study would be relatively maintenance free. The main expense, when it is unused, is income lost from alternative use of the land it occupies.

## CONCLUSIONS

1. Recharge basins excavated through slowly permeable soils in the Southern High Plains are an effective technique for artificially recharging surface runoff to the Ogallala Aquifer.

2. Corrugating the bottom of a basin up and down the slope and removing rainfall runoff through a pipe drain can make the recharge basin self-cleaning.

## SUMMARY

Turbid storm runoff was pumped from a 16-ha (40-acre) playa (wet weather lake) into a 0.20-ha (0.5-acre) recharge basin for replenishing the Ogallala Aquifer in the Southern High Plains. The average recharge rate during 187 days of flooding over a 7 yr interval was 0.373 m/d (1.22 ft/day).

## ACKNOWLEDGMENT

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## APPENDIX.—REFERENCES

1. Aronovici, V. S., Schneider, A. D., and Jones, O. R., "Basin Recharge of the Ogallala Aquifer," *Journal of the Irrigation and Drainage Division*, ASCE, Vol. 98, No. IR1, Mar., 1972, pp. 65-76.
2. Brown, R. F., and Signor, D. C., "Artificial Recharge Experiments and Operations on the Southern High Plains of Texas and New Mexico," *Water-Resources Investigations* 10-73, U.S. Geological Survey, May, 1973, p. 53.
3. Cronin, J. G., "A Summary of the Occurrence and Development of Ground Water in the Southern High Plains of Texas," *Water-Supply Paper* 1693, U.S. Geological Survey, 1964, p. 88.
4. Goss, D. W., Smith, S. J., Stewart, B. A., and Jones, O. R., "Fate of Suspended Solids during Basin Recharge," *Water Resources Research*, Vol. 9, No. 3, June, 1973, pp. 668-675.
5. Hauser, V. L., and Lotspeich, F. B., "Treatment of Playa Lake Water for Recharge Through Wells," *Transactions of the ASAE*, Vol. 11, No. 1, Jan.-Feb., 1968, pp. 108-111.
6. Hauser, V. L., and Signor, D. C., "Water Conservation and Ground Water

Recharge Research—Texas High Plains,” Miscellaneous Publication 850, Texas Agric. Expt. Sta., College Station, Tex., Sept., 1967, p. 10.

7. Jones, O. R., Goss, D. W., and Schneider, A. D., “Surface Plugging during Basin Recharge of Turbid Water,” *Transactions of the ASAE*, Vol. 17, No. 6, Nov.–Dec., 1974, pp. 1011–1014, 1019.
8. Jones, O. R., Goss, D. W., and Schneider, A. D., “Management of Recharge Basins in the Southern Great Plains,” *Transactions of the ASAE*, Vol. 24, No. 4, July–Aug., 1981, pp. 977–980, 987.